Masses, Accretion Rates and Inclinations of AGNs

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Received ...; accepted ...

Abstract. We assume that the gravitational instability of standard thin accretion disks leads to the Broad Line Regions (BLRs), the B band luminosity comes from standard thin disk and the motion of BLRs is virial. The central black hole masses, the accretion rates and the disk inclinations to the line of sight for 17 Seyfert 1 galaxies and 17 Palomar-Green (PG) quasars have been calculated. Our results are sensitive to α parameter of the standard α disk. With the same values of α ($\alpha = 1$), calculated central black hole masses for 17 Seyfert 1 galaxies are consistent with that from Kaspi et al. (2000) while that for 17 PG quasars are larger than that from Kaspi et al. (2000) by almost 2 orders of magnitude. Inclinations of 17 Seyfert 1 galaxies are about 6 times larger than that of 17 PG quasars. These inclinations, with a mean value of 32^o for 17 Seyfert 1 galaxies that agrees well with the result obtained by fitting the iron $K\alpha$ lines of Seyfert 1 galaxies observed with ASCA (Nandra et al. 1997) and the result obtained by Wu & Han (2001), provide further support for the orientation-dependent unification scheme of active galactic nuclei. There is a relation between the FWHM of Hβ and the inclination, namely the inclination is smaller in AGNs with smaller FWHM of Hβ. The effect of inclinations in narrow line Seyfert 1 galaxies (NLS1s) should be considered when one studies the physics of NLS1s. The need of higher value of α for PG quasars maybe shows that our model is not suitable for PG quasars if we think inclinations of PG quasars are in the inclination levels of Seyfert 1 galaxies. With our model, we also show that the size of BLRs relates not only to the luminosity, but also to the accretion rates. More knowledge of BLRs dynamics, accretion disks and optical luminosity are needed to improve the determinations of black hole masses, accretion rates and inclinations in AGNs.

Key words. accretion, accretion disks – galaxies: active – galaxies: nuclei – quasars: Seyfert

1. Introduction

Broad emission lines are one of the dominant features of many Active Galactic Nuclei (AGNs) spectrum. Broad Line Regions (BLRs) play a particularly important role in our understanding of AGNs by virtue of its proximity to the central source. With reverberation mapping technique the sizes of the BLRs can be obtained through the study of correlated variations of the lines and continuum fluxes (Peterson 1993). The BLR sizes for 17 Seyfert 1 galaxies (Wandel et al. 1999) and for 17 PG quasars (Kaspi et al. 2000) have been recently obtained. Assuming the Keplerian motions and the random orbits of the BLRs, the central black hole masses also have been obtained. In order to underline the physics of AGNs, these masses have been used to check the relations with other parameters of AGNs, such as the radio power (Ho 2002), the X-ray excess variance (Lu & Yu 2001), the velocity dispersions of their host galaxies (Ferrarese et al. 2001; Gebhardt et al. 2000b).

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Based on the unified model of AGNs, the wide variety of AGN phenomena we see is due to a combination of real differences in a small number of physical parameters (e.g. luminosity) coupled with apparent differences which are due to observer-dependent parameters (e.g. orientation). AGNs with wide emission lines from BLRs are oriented at a preferred angle from which BLRs is visible. No edge-on disks in AGNs with wide emission lines would be seen (Urry & Padovani 1995). Therefore, inclinations of AGNs with wide emission lines are generally expected to be small although further evidence is obviously needed. It is important to test it with inclinations of AGNs. Random mean angle is often assumed in calculated black hole masses with the reverberation mapping method. Some authors (McLure & Dunlop 2001; Wu & Han 2001) have shown it is necessary to consider the effects of the inclination.

Though it is powerful for size determination, currently reverberation mapping method does not provide the velocity field of the BLRs, and can not distinguish between radial and rotational motions. Because there is no consensus about the dynamics of the BLRs, there has been little progress in understanding the physics of this region.

Recently some authors (Collin & Hure 2001) suggest the gravitationally unstable disc is the source which releases BLRs in the medium.

In this paper, we also assume the gravitational instability leads to the formation of BLRs. With the analysis formulae of standard thin accretion disks and the observational sizes of the BLRs, we calculate the central masses, accretion rates and inclinations for 34 AGNs. We want to give the clues to the origin of BLRs, the values of three parameters of accretion disks and the inclination effect in mass determination in AGNs. The paper is structured as follows. In Sect. 2, we describe our model and available data. In sect. 3, we give our calculational results. Our discussion and conclusions are presented in the last section.

2. Calculation

2.1. Formulae

First, we consider gravitational potential energy at R away from the center of the black hole is released at the rate $GM\dot{M}/R$, where M is the central black hole mass and $\dot{M}$ is the accretion rate; from the virial theorem, half of this goes into heating the gas, and the other half is radiated away. Thus the disk temperature at R is $T = (\frac{3GM\dot{M}}{8\pi\sigma R^3}(1-(R/R_s)^{1/2}))^{1/4}$ (Frank et al. 1992), where G is the gravitational constant, σ is Stefan-Boltzmann constant, $R_s = 2GM/c^2$ is the Schwarzchild radius of the black hole with the mass of M. For $R >> R_s$, this can be simplified, $T = (\frac{3GM\dot{M}}{8\pi\sigma R_s^3})^{1/4}(R/R_s)^{-3/4} = T_\star(R/R_s)^{-3/4}$. As a first approximation we can assume the accretion disk radiates locally like a blackbody and the specific luminosity is $L_\nu = 2.4 \times 10^{-18} R_s^2 cosi T_\star^{8/3} \nu^{1/3}$ ergs s^{-1}Hz^{-1} (Peterson 1997). We obtained the B band luminosity, $L^B = 0.5312 \times 10^{44} \dot{M}^{2/3} M^{2/3} cosi$ ergs s^{-1}, where i is the inclination of the disk to the line of sight and the frequency is between 3900$\mathring{A}$ and 4900$\mathring{A}$. We can rewrite it in terms of $R_{14} = R/(10^{14} cm)$, $M_8 = M/(10^8\,\mathrm{M}_\odot)$, $L_9^B = L^B/(10^9 L\odot)$ and $\dot{M}_{26} = \dot{M}/(10^{26}\mathrm{g\ s}^{-1})$,

$$L_9^B = 13.8 \dot{M}_{26}^{2/3} M_8^{2/3} cosi. \quad (1)$$

Second, we assume that the gravitational instability of the disk at large radii leads to the formation of BLRs. The criterion is $Q = \frac{\Omega^2}{\pi G \rho} \leq 1$ (Golreich & Lynden-Bell 1965) , where Ω is the Keplerian angular velocity $(GM/R^3)^{1/2}$ and ρ is the local mass density. We adopted the solutions of ρ for the standard thin disk from Shakura & Sunyaev (1973), $\rho = 3.1 \times 10^{-5} \alpha^{-7/10} \dot{M}_{26}^{11/20} M_8^{5/8} R_{14}^{-15/8} f^{11/5}$ g cm^{-3}, where $f = (1-(R/R_s)^{1/2})^{1/4}$, α is the parameter of the standard α disk. We adopted $f = 1$. The value of α in AGNs is often between 0 and 1. We obtained the size of the BLRs,

$$R_{14} = 880 \alpha^{28/45} Q^{-8/9} \dot{M}_{26}^{-22/45} M_8^{1/3}. \quad (2)$$

Third, assuming the Keplerian velocity of the BLRs, then the so-called virial mass estimated for the central black hole is given by $M = \frac{V_{FWHM}}{4(sini^2+A^2)} RG^{-1}$ (McLure & Dunlop 2001), where V_{FWHM} is the FWHM of the Hβ emission line, i is the inclination, A is the ratio of the random isotropic characteristic velocity to the Keplerian velocity of the disk and A is omitted here (Wu & Han 2001). Then we can get,

$$V_3 = 3.89 \alpha^{-14/45} \dot{M}_{26}^{11/45} M_8^{1/3} sini. \quad (3)$$

where $V_3 = V_{FWHM}/(1000\mathrm{km\ s}^{-1})$.

2.2. Data

The absolute B band magnitudes are adopted from Veron-Cetty et al. (2001), which are calculated by adopting an average optical index of -0.5 and accounting for Galactic redding and K-correction. Giveon et al. (1999) have calculated the median absolute magnitude for the PG sample that Kaspi et al. (2000) have used. The values of absolute B band magnitude from Giveon et al. (1999) are often different from the values we adopted from Veron-Cetty et al. (2001). The optical variability is a common property for AGNs (Giveon et al. 1999). The B magnitude of Seyfert 1 galaxies might be affected from their host galaxies. Therefore we adopt one B band magnitude uncertainty when we calculate the uncertainty of our calculated results. The sizes of the BLRs for 17 Seyfert 1 galaxies and 17 PG quasars are adopted from Kaspi et al. (2000). The central black hole masses calculated from reverberation mapping are also adopted from Kaspi et al. (2000). The properties of 34 AGNs are listed in Table 1. Column 2,3,4 are respectively absolute B band magnitudes, sizes of BLRs and FWHMs of $H\beta$.

3. Results

Using Eq. (1), Eq. (2), Eq. (3), we can calculate the central black hole masses (M) , the accretion rate ($\dot{M}$) and the inclination (i) knowing absolute B band luminosity (L^B), sizes of the BLRs (R) and FWHMs of Hβ (V_{FWHM}). Errors of FWHMs of Hβ are not included in our calculation. α is 1 in all the calculations and the uncertainties of our calculated results are estimated by considering $1/4 \leq Q \leq 4$ (Golreich & Lynden-Bell 1965), errors of sizes of BLRs and one absolute B band magnitude uncertainty except in situations where we declare otherwise. We use Q=0.25, the lower limits of BLRs sizes and the upper limits of the absolute B magnitude to give one directional limits of our results. We calculate the another directional limits of our results using Q=4, the upper limits of BLRs sizes and the lower limits of the absolute B magnitude. We present the accretion rate in units of Eddington accretion rate, $\dot{m} = \dot{M}_{26} 1.578/(3.88 M_8)$ (Laor & Netzer 1989). The results are shown in Table 1. Column (6) is our calculated BH masses. Column (7) is inclinations of the disk to the line of sight. Column (8) and Column (9) are the accretion rates and the accretion rate in unites of Eddington accretion rate, respectively. Column (10) lists the the radio loudness (Nelson 2001). Column (11) is the available

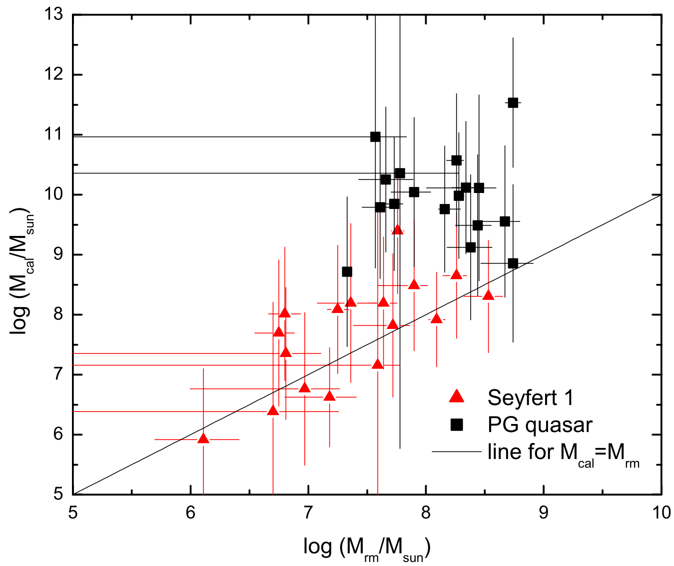

Fig. 1. M_{cal} versus $M_{rm}(\alpha = 1)$. The triangle denotes Seyfert 1 galaxy and the square denotes PG quasar. The beeline represents $M_{cal} = M_{rm}$.

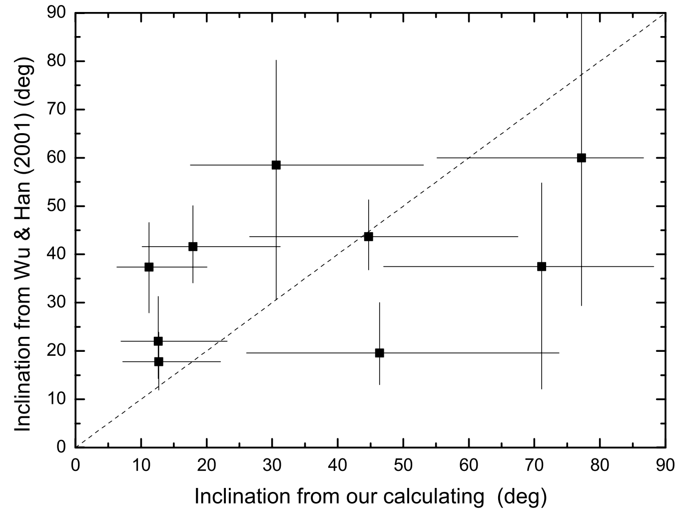

Fig. 2. Inclinations form Wu & Han (2001) versus our calculated inclinations. The dash line presents inclinations from Wu & Han (2001) and our calculated inclinations are consistent.

nuclear radio loudness (Ho & Peng 2001). Column (12) is inclinations for the same AGNs from Wu & Han (2001).

We also use the bootstrap method, which uses the actual data and their errors to generate many data following a gaussian distribution, to calculate uncertainties of our results. Based on the measured values and their errors of some parameters (such as BLRs sizes, FWHMs of $H\beta$ line, B magnitude), independent 20000 gaussian distribution data points of these parameters are generated, which are used to drive 20000 values of our results. We can get the values and uncertainties of our results using gaussian distribution to fit 20000 results. The values and uncertainties of our results from the bootstrap method are almost the same as our results listed in Table 1.

3.1. Masses

Assuming random disk inclinations to the line of sight, these 34 central black hole reverberation mapping masses M_{rm} have been obtained (Kaspi et al. 2000). Here we plot in Fig.1 our calculated central black hole masses considering the effects of inclinations (M_{cal}) versus the reverberation mapping masses (M_{rm}). Fig.1 shows that, though M_{cal} of 17 PG quasars are lager than their M_{rm} , M_{cal} of 17 Seyfert 1 galaxies are consistent with M_{rm} of them. We have a χ^2 (Press et al. 1992, p616) test to show if our calculated BH masses M_{cal} are consistent with M_{rm} from Kaspi et al. (2000). χ^2 and probability are 1.81 and 99.9% for 17 Seyfert 1 galaxies. For 17 PG quasars χ^2 and probability are 10.98 and 81% respectively.

3.2. Inclinations

By fitting the observed iron $K\alpha$ line profile with the accretion disk model, Nandra et al. (1997) estimated the inclinations, with a mean value of 30^o, for 18 Seyfert 1 galaxies. Wu & Han (2001) developed a simple method to drive the inclinations (with a mean value of 36^o) for a sample of 11 Seyfert 1 galaxies that have both measured bulge velocity dispersion and BH masses estimated by reverberating mapping technique. The mean and the rms of the mean of our calculated inclinations for 17 Seyfert 1 galaxies are 32.2 ± 5.5 (deg), which are consistent with the results of Nandra et al. (1997) and Wu & Han (2001). In fig.2 we plot inclinations from Wu & Han (2001) versus our calculated inclinations for 9 common Seyfert 1 galaxies. The dash line in Fig.2 presents inclinations from Wu & Han (2001) and our calculated inclinations are consistent. Our calculated inclinations of 17 Seyfert 1 galaxies provide further support to the orientation-dependent unification scheme of AGNs. The mean and error of our calculated inclinations for 17 PG quasars are 5.65 ± 1.08 (deg), which are smaller compared to that of Seyfert 1 galaxies.

A positive correlation of inclinations with observed FWHMs of the $H\beta$ line has been found (Wu & Han 2001). Fig. 3 displays the inclination of the disk to the line of sight versus the width of Hβ. We can find there is a correlation for Seyfert 1 galaxies between FWHMs of Hβ and inclinations. A simple least square linear regression (Press et al. 1992, p655) gives $i = (12.95 \pm 10.65) + (4.7 \pm 2.29)(V_{FWHM}/1000\mathrm{kms}^{-1})$, with a Pearson correlation coefficient of R=0.47 corresponding to a probability of P=0.058 that the correlation is caused by a random factor. A minimum χ^2 fit considering the errors of both parameters (Press et al. 1992, p660) gives $i = (-0.80 \pm 4.43) +$

Name (1)	M_B (Mag) (2)	R_{BLR} (lt days) (3)	$V_{H\beta}$ (1000km/s) (4)	$log_{10}M_{rm}$ ($M_\odot$) (5)	$log_{10}M_{cal}$ ($M_\odot$) (6)	i (deg) (7)	$log_{10}\dot{M}$ ($M_\odot/yr$) (8)	$\dot{m}$ (9)	R_{ro} (10)	R_{nucl} (11)	i_{disp} (deg) (12)
3C120	-20.8	42^{+27}_{-20}	1.91 ± 0.12	$7.36^{+0.22}_{-0.28}$	$8.19^{+1.26}_{-1.32}$	$12.6^{+10.5}_{-5.7}$	$0.14^{+0.76}_{-0.67}$	$0.228^{+27.9}_{-0.2}$	16.8	–	$22.0^{+9.3}_{-7.7}$
3C390.3	-21.6	$22.9^{+6.3}_{-8.0}$	10 ± 0.8	$8.53^{+0.12}_{-0.21}$	$8.30^{+1.02}_{-0.94}$	$48.0^{+24.0}_{-19.7}$	$0.76^{+0.84}_{-0.61}$	$0.728^{+42.6}_{-0.7}$	198	–	–
Akn120	-22.2	$37.4^{+5.1}_{-6.3}$	5.8 ± 0.48	$8.26^{+0.08}_{-0.12}$	$8.65^{+1.06}_{-1.04}$	$21.7^{+15.6}_{-9.2}$	$0.56^{+0.55}_{-0.49}$	$0.207^{+7.9}_{-0.2}$	0.25	–	–
F9	-23.0	$16.3^{+3.3}_{-7.6}$	5.78 ± 0.65	$7.9^{+0.11}_{-0.31}$	$8.49^{+1.09}_{-1.09}$	$17.1^{+12.7}_{-7.3}$	$1.18^{+0.55}_{-0.51}$	$1.277^{+54.8}_{-1.2}$	0	–	–
IC4329A[a]	-20.1	$1.4^{+3.3}_{-2.9}$	5.05 ± 2.07	$6.7^{+0.56}_{-3.70}$	$6.38^{+1.47}_{-1.82}$	$58.0^{+25.1}_{-25.8}$	$1.93^{+2.19}_{-1.17}$	$903.80^{+9.4E6}_{-901.7}$	10.2	–	–
Mrk79	-20.9	$17.7^{+4.8}_{-8.4}$	4.47 ± 0.85	$7.72^{+0.14}_{-0.34}$	$7.82^{+1.09}_{-1.20}$	$30.6^{+22.5}_{-13.1}$	$0.66^{+0.83}_{-0.56}$	$1.76^{+185.8}_{-1.7}$	0.8	–	$58.5^{+21.7}_{-27.9}$
Mrk110	-20.6	$18.8^{+6.3}_{-6.6}$	1.43 ± 0.12	$6.75^{+0.13}_{-0.20}$	$7.70^{+1.16}_{-1.22}$	$11.2^{+8.9}_{-4.9}$	$0.52^{+0.65}_{-0.56}$	$1.70^{+123.6}_{-1.7}$	1.6	–	$37.4^{+9.2}_{-9.5}$
Mrk335	-21.7	$16.4^{+5.1}_{-3.2}$	1.62 ± 0.12	$6.8^{+0.14}_{-0.14}$	$8.01^{+1.15}_{-1.11}$	$8.2^{+6.2}_{-3.6}$	$0.85^{+0.53}_{-0.55}$	$1.79^{+76.5}_{-1.7}$	0.2	0.62	–
Mrk509	-23.3	$76.7^{+6.3}_{-6.0}$	2.27 ± 0.12	$7.76^{+0.05}_{-0.05}$	$9.40^{+1.05}_{-1.04}$	$5.0^{+3.7}_{-2.1}$	$0.43^{+0.45}_{-0.45}$	$0.028^{+0.8}_{-0.02}$	0.4	–	–
Mrk590	-21.6	$20.0^{+4.4}_{-2.9}$	2.47 ± 0.12	$7.25^{+0.10}_{-0.09}$	$8.09^{+1.11}_{-1.07}$	$12.7^{+9.4}_{-5.5}$	$0.73^{+0.50}_{-0.52}$	$1.13^{+41.1}_{-1.1}$	0.5	1.62	$17.8^{+6.1}_{-5.9}$
Mrk817	-22.3	$15.0^{+4.2}_{-3.4}$	4.49 ± 0.18	$7.64^{+0.11}_{-0.12}$	$8.19^{+1.12}_{-1.10}$	$17.9^{+13.3}_{-7.7}$	$1.06^{+0.57}_{-0.55}$	$1.88^{+86.6}_{-1.8}$	0.8	1.21	$41.6^{+8.5}_{-7.5}$
NGC3227[b]	-18.7	$10.9^{+5.6}_{-10.9}$	4.92 ± 0.49	$7.59^{+0.19}_{-4.60}$	$7.16^{+0.94}_{-2.60}$	$71.1^{+17.1}_{-24.1}$	$0.63^{+3.49}_{-0.82}$	$7.70^{+9.4E6}_{-7.6}$	4.7	1.12	$37.5^{+17.5}_{-25.4}$
NGC3783	-19.7	$4.5^{+3.6}_{-3.1}$	3.79 ± 1.16	$6.97^{+0.30}_{-0.97}$	$6.76^{+1.21}_{-1.27}$	$47.5^{+26.7}_{-20.5}$	$1.15^{+1.26}_{-0.79}$	$62.8^{+21545.3}_{-62.2}$	0.6	–	–
NGC4051	-16.8	$6.5^{+6.6}_{-4.1}$	1.17 ± 0.06	$6.11^{+0.30}_{-0.41}$	$5.91^{+1.28}_{-1.19}$	$46.4^{+27.4}_{-20.3}$	$0.25^{+1.17}_{-0.85}$	$55.11^{+12478.6}_{-54.7}$	6	0.87	$19.5^{+10.4}_{-6.6}$
NGC4151	-18.7	$3.0^{+1.8}_{-1.4}$	5.23 ± 0.92	$7.18^{+0.23}_{-0.38}$	$6.62^{+0.89}_{-0.83}$	$77.2^{+9.5}_{-22.1}$	$1.42^{+1.09}_{-0.90}$	$159.5^{+12998.9}_{-157.0}$	5.6	0.49	$60.0^{+30.0}_{-30.6}$
NGC5548	-20.7	$21.2^{+2.4}_{-0.7}$	6.3 ± 0.4	$8.09^{+0.07}_{-0.07}$	$7.92^{+0.98}_{-0.79}$	$44.7^{+22.8}_{-18.1}$	$0.56^{+0.59}_{-0.52}$	$1.13^{+25.7}_{-1.1}$	1.5	1.24	$43.7^{+7.6}_{-6.9}$
NGC7469	-21.6	$4.9^{+0.6}_{-1.1}$	3 ± 1.58	$6.81^{+0.30}_{-3.81}$	$7.35^{+1.06}_{-1.1}$	$18.0^{+13.4}_{-7.6}$	$1.48^{+0.57}_{-0.48}$	$34.23^{+1568.6}_{-33.2}$	3	3.2	–
PG0026	-24.0	113^{+18}_{-21}	2.1 ± 0.14	$7.73^{+0.07}_{-0.10}$	$9.85^{+1.09}_{-1.11}$	$3.4^{+2.6}_{-1.4}$	$0.39^{+0.51}_{-0.49}$	$0.009^{+0.4}_{-0.009}$	1.6	–	–
PG0052	-24.5	134^{+31}_{-23}	3.99 ± 0.24	$8.34^{+0.11}_{-0.12}$	$10.12^{+1.12}_{-1.10}$	$5.1^{+3.9}_{-2.2}$	$0.42^{+0.51}_{-0.52}$	$0.0052^{+0.2}_{-0.005}$	0.3	–	–
PG0804	-23.9	156^{+15}_{-13}	2.98 ± 0.051	$8.28^{+0.04}_{-0.04}$	$9.98^{+1.06}_{-1.05}$	$4.8^{+3.5}_{-2.0}$	$0.20^{+0.46}_{-0.46}$	$0.0042^{+0.1}_{-0.004}$	0.2	–	–
PG0844	-23.1	$24.2^{+10}_{-9.1}$	2.73 ± 0.12	$7.33^{+0.02}_{-0.02}$	$8.72^{+1.19}_{-1.25}$	$7.5^{+6.0}_{-3.3}$	$0.99^{+0.66}_{-0.59}$	$0.48^{+38.7}_{-0.47}$	0.1	–	–
PG0953	-25.6	151^{+22}_{-27}	2.885 ± 0.065	$8.26^{+0.06}_{-0.09}$	$10.57^{+1.08}_{-1.11}$	$2.3^{+1.8}_{-1.0}$	$0.63^{+0.51}_{-0.48}$	$0.003^{+0.1}_{-0.0028}$	1.1	–	–
PG1211	-24.0	101^{+23}_{-29}	1.832 ± 0.081	$7.61^{+0.09}_{-0.15}$	$9.79^{+1.12}_{-1.19}$	$3.0^{+2.3}_{-1.3}$	$0.45^{+0.59}_{-0.52}$	$0.012^{+0.7}_{-0.01}$	0.1	–	–
PG1226	-26.9	387^{+58}_{-50}	3.416 ± 0.072	$8.74^{+0.07}_{-0.07}$	$11.53^{+1.08}_{-1.08}$	$1.4^{+1.1}_{-0.6}$	$0.45^{+0.48}_{-0.48}$	$2.11E-4^{+0.007}_{-2.05E-4}$	1621.2	–	–
PG1229	-22.4	50^{+24}_{-23}	3.44 ± 0.12	$8.74^{+0.17}_{-0.27}$	$8.85^{+1.21}_{-1.31}$	$11.6^{+9.6}_{-5.1}$	$0.44^{+0.75}_{-0.62}$	$0.1^{+11.2}_{-0.097}$	0.3	–	–
PG1307	-24.6	124^{+45}_{-80}	4.19 ± 0.14	$8.45^{+0.14}_{-0.45}$	$10.11^{+1.17}_{-1.55}$	$5.2^{+4.8}_{-2.3}$	$0.49^{+0.96}_{-0.57}$	$0.006^{+2.0}_{-0.006}$	0.2	–	–
PG1351	-24.1	227^{+149}_{-72}	1.17 ± 0.16	$7.66^{+0.23}_{-0.23}$	$10.25^{+1.27}_{-1.21}$	$1.6^{+1.3}_{-0.8}$	$0.05^{+0.61}_{-0.67}$	$0.0016^{+0.1}_{-0.0015}$	0	–	–
PG1411	-24.7	102^{+38}_{-37}	2.456 ± 0.096	$7.90^{+0.14}_{-0.20}$	$10.04^{+1.17}_{-1.24}$	$3.0^{+2.4}_{-1.3}$	$0.61^{+0.65}_{-0.58}$	$0.01^{+0.7}_{-0.009}$	0.2	–	–
PG1426	-23.4	95^{+31}_{-39}	6.25 ± 0.39	$8.67^{+0.13}_{-0.24}$	$9.55^{+1.15}_{-1.26}$	$13.0^{+10.5}_{-5.8}$	$0.34^{+0.70}_{-0.56}$	$0.016^{+1.4}_{-0.015}$	0.2	–	–
PG1613	-23.5	39^{+20}_{-14}	7 ± 0.38	$8.38^{+0.18}_{-0.20}$	$9.12^{+1.22}_{-1.21}$	$15.4^{+12.1}_{-6.8}$	$0.84^{+0.66}_{-0.63}$	$0.13^{+10.0}_{-0.13}$	0.8	–	–
PG1617	-23.4	85^{+19}_{-25}	5.12 ± 0.85	$8.44^{+0.12}_{-0.19}$	$9.49^{+1.11}_{-1.18}$	$10.8^{+8.4}_{-4.7}$	$0.40^{+0.60}_{-0.51}$	$0.02^{+1.2}_{-0.02}$	0.7	–	–
PG1700[c]	-25.8	88^{+190}_{-182}	2.18 ± 0.17	$7.78^{+0.51}_{-4.78}$	$10.36^{+1.62}_{-4.59}$	$1.7^{+1.7}_{-0.8}$	$0.96^{+3.99}_{-1.01}$	$0.01^{+3.9E6}_{-0.01}$	8.5	–	–
PG1704	-25.6	319^{+184}_{-285}	0.89 ± 0.28	$7.57^{+0.26}_{-4.57}$	$10.97^{+1.25}_{-2.19}$	$0.6^{+0.81}_{-0.3}$	$0.23^{+1.59}_{-0.65}$	$4.73E-4^{+2.8}_{-4.6E-4}$	562.8	–	–
PG2130	-22.9	200^{+67}_{-18}	2.41 ± 0.15	$8.16^{+0.13}_{-0.05}$	$9.76^{+1.16}_{-1.05}$	$5.7^{+4.20}_{-2.5}$	$-0.18^{+0.46}_{-0.56}$	$0.003^{+0.1}_{-0.003}$	0.4	–	–

Table 1. The properties of the 34 AGNs. Col.1: name, Col.2: absolute B band magnitude from Veron-Cetty et al. (2001), Col.3: size of BLRs in lt days from Kaspi et al. (2001), Col.4: FWHM (in $1000kms^{-1}$) of Hβ from Kaspi et al. (2000), Col.5:log of the reverberation mapping BH mass in $M_\odot$ from Kaspi et al. (2000), Col.6:log of our calculated BH mass in $M_\odot$, Col.7: calculated inclinations (in deg) to our sight, Col.8: log of accretion rates in $M_\odot/yr$, Col.9 the accretion rate in units of Eddington accretion rate , Col.10: the radio loudness from Nelson (2001) , Col.11, the nuclear radio loudness from Ho, L. C. and Peng, C. Y. (2001), Col.12, inclinations from Wu & Han (2001). [a],[b],[c]: the lower limit of the size of BLRs is not larger than zero and it leads to the very high accretion rate.

$(4.15 \pm 1.59)(V_{FWHM}/1000\text{kms}^{-1})$, with χ^2 and probability of 6.04 and 73%, respectively. There also exists a correlation between FWHMs of Hβ and inclinations for 17 PG quasars. A simple least square linear regression gives $i = (-1.75 \pm 1.3) + (2.29 \pm 0.36)(V_{FWHM}/1000\text{kms}^{-1})$, with R=0.85 (P$< 10^{-4}$). A minimum χ^2 fit considering the errors of both parameters gives $i = (1.85 \pm 1.47) + (0.19 \pm 0.53)(V_{FWHM}/1000\text{kms}^{-1})$, with χ^2 and probability of 6.9 and 65%, respectively.

A possible anticorrelation of inclinations with the nuclear radio loudness has been found (Wu & Han 2001). Fig.4 displays the inclinations versus the radio loudness, defined by the ratio between 5 GHz radio luminosity and B-band optical luminosity (Nelson 2001). Because there exist the contaminations to the luminosity of galactic nucleus from the host galaxies, using the nuclear radio loudness will be better to describe the nature of galactic nuclei. We plot in Fig.5 the inclinations versus the nuclear radio loudness, defined by the ratio between 5 GHz nuclear radio luminosity and B-band nuclear optical luminosity (Ho & Peng 2001). Although there are only eight AGNs with available data for nuclear radio loudness, Fig.5 still shows the tendency that Seyfert 1 galaxies with the larger nuclear radio loudness may have smaller inclinations. A simple least square linear regression gives $i = (53.9 \pm 17.9) + (-13.0 \pm 11.8)(R_{nuc})$, with a correlation coefficient of R=0.41 corresponding to a probability of P=0.31 that the correlation is caused by a random factor. It is consistent with the result of Wu & Han (2001).

Considering the disk inclinations we calculate the intrinsic width of Hβ, which is approximately equal to the observed width of Hβ divided by $sin(i)$. In Fig.6 we plot the intrinsic width of Hβ versus the observed width of Hβ.

3.3. Accretion Rates

In Fig.7 we plot M_{cal} versus the accretion rates $\dot{M}$ and in Fig.8 we plot M_{cal} versus the accretion rates in terms of the Eddington accretion rate. Our calculated accretion rates for PG quasars are consistent with that from Laor

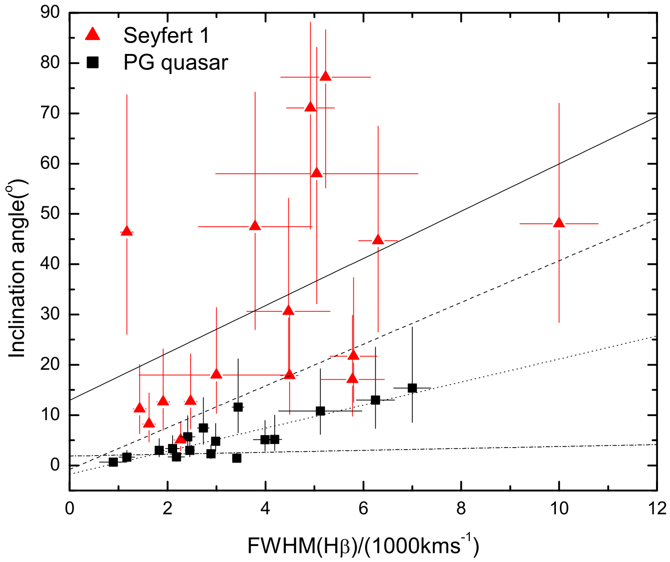

Fig. 3. Inclination versus width of Hβ($\alpha = 1$). The denotation is the same as that in Fig.1. The solid line and dash line show the simple least square linear fit for Seyfert 1 galaxies and Quasars, respectively. The dot line and dash dot line show the minimum χ^2 fit with errors of both parameters considered for Seyfert 1 galaxies and quasars, respectively.

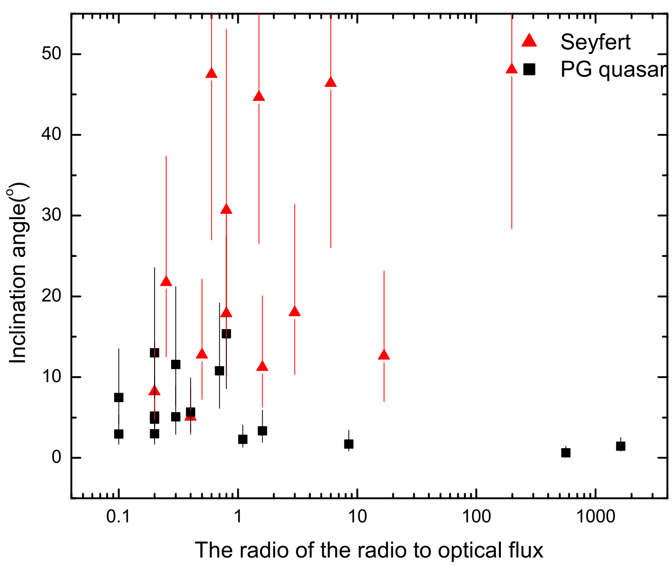

Fig. 4. Inclinations versus the radio loudness($\alpha = 1$). The denotation is the same as that in Fig.1.

(1990). Our calculated accretion rates for Seyfert 1 galaxies are larger and we discuss it in next section.

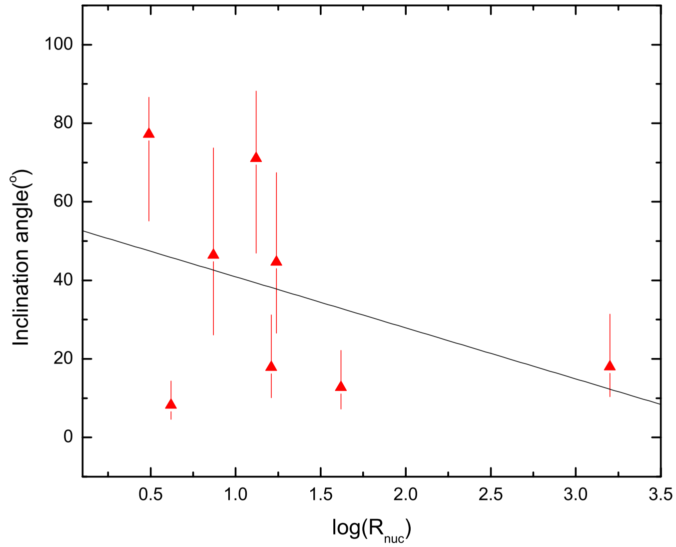

Fig. 5. Inclinations versus the nuclear radio loudness($\alpha = 1$). The denotation is the same as that in Fig.1. The solid line shows the simple least square linear fit.

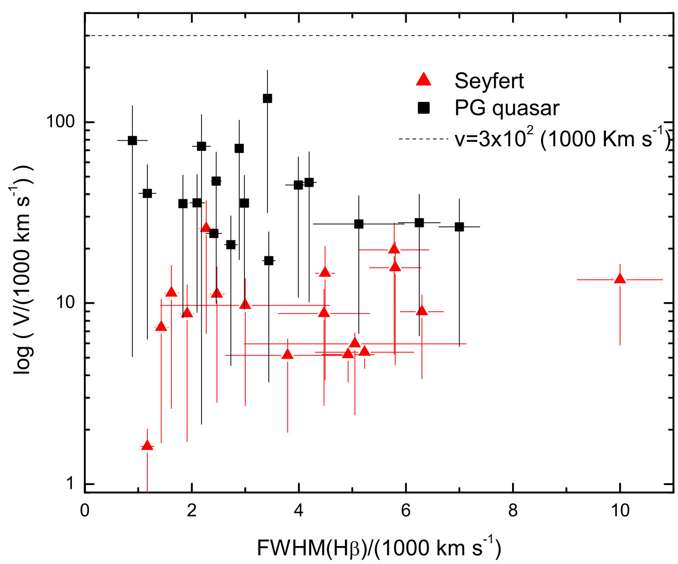

Fig. 6. The intrinsic width of Hβ versus the observed width of Hβ($\alpha = 1$). The straight dash line shows the velocity of light. The denotation is the same as that in Fig.1.

3.4. $M_{bh} - \sigma$ Relation

Ferrarese et al. (2001) measured bulge velocity dispersions of AGNs and found good agreement between BH masses obtained from reverberating mapping technique and from the $M_{bh} - \sigma$ relation as defined by quiescent galaxies. In Fig.9 we plot our calculated BH masses considering inclinations versus the bulge velocity dispersion of AGNs. The dash line in Fig.9 is the best linear fit to

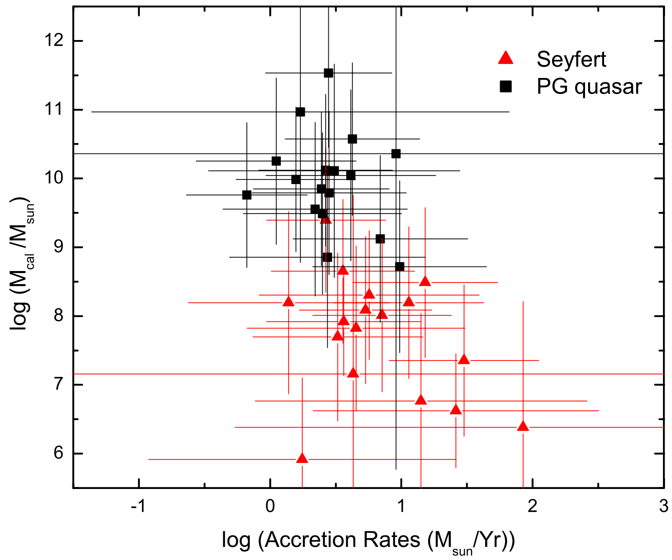

Fig. 7. M_{cal} versus the accretion rates ($M_\odot$/yr) ($\alpha = 1$). The denotation is the same as that in Fig.1.

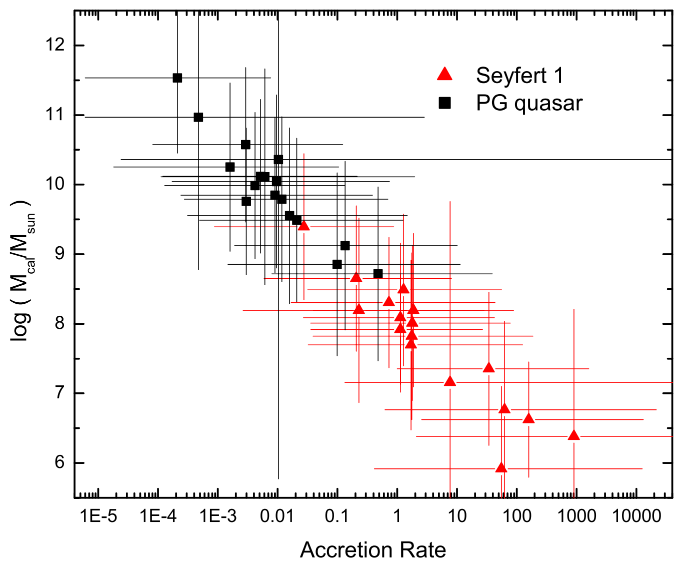

Fig. 8. M_{cal} versus the accretion rate in units of the Eddington accretion rate($\alpha = 1$). The denotation is the same as that in Fig.1.

the $M_{bh} - \sigma$ relation as published by Merritt & Ferrarese (2001) for nearby normal galaxies. Although there is a large scatter our calculated BH mass is also consistent with the $M_{bh} - \sigma$ relation as defined by quiescent galaxies. A minimum χ^2 fit for our calculated BH mass and the bulge velocity dispersion considering error of both parameters gives $log(M/(10^7\,\mathrm{M}_\odot)) = (-1.63 \pm 5.49) + (4.32 \pm 2.65) log(\sigma/(\mathrm{kms}^{-1}))$, with χ^2 and probability of 1.55 and 98%, respectively. The minimum χ^2 fit for the

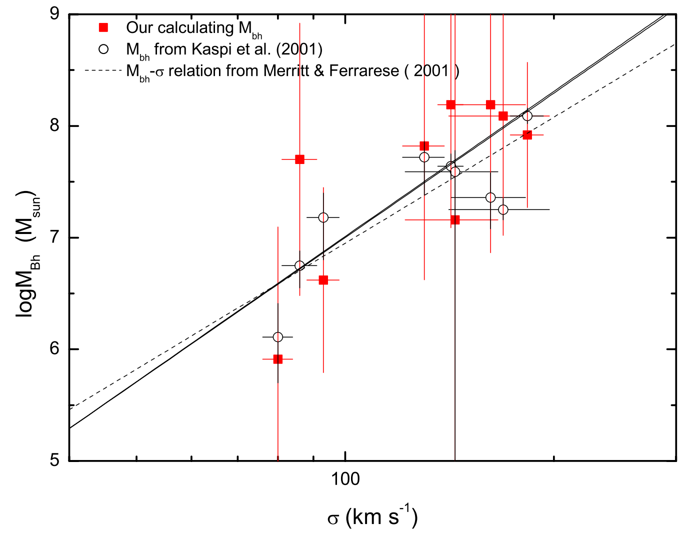

Fig. 9. Black hole mass versus velocity dispersion in the bulges of the hosts of AGNs. Solid square denotes our calculated BH mass and open circle denotes the reverberating mapping BH mass. The dash line is the best linear fit to the $M_{bh} - \sigma$ relation as published by Merritt & Ferrarese (2001) for nearby normal galaxies. The solid line is a minimum χ^2 fit line for our calculated BH mass and bulge velocity dispersion considering the errors of both parameters.

reverberation mapping BH mass (Kaspi et al. 2000) and the bulge velocity dispersion gives $log(M/(10^7\,\mathrm{M}_\odot)) = (-1.64 \pm 1.17) + (4.3 \pm 0.55) log(\sigma/(\mathrm{kms}^{-1}))$ ($\chi^2 = 14.2$ and probability is 0.05), which is very similar to our results.

3.5. Uncertainties of Our Results

We also adopt $\alpha = 0.1$ and $\alpha = 0.01$ to calculate $\Delta(logM) = log(M_{cal}) - log(M_{rm})$ (Q=1 and not considering the uncertainties of sizes of BLRs and absolute B magnitudes). The mean and the standard error(SE) of $\Delta(logM)$ are calculated. The results are shown in Table2. From Table2, we can find the mean of $\Delta log(M)$ for Seyfert 1 galaxies is smaller than that of PG quasars with the same value of α. With the decrease of α the mean of $\Delta log(M)$ becomes larger. In table 3,4 we list the mean and error of uncertainties of our results for Seyfert 1 galaxies and PG quasars, respectively. Considering the effect of uncertainty of B band magnitude we find the uncertainties of calculated inclinations, masses and accretion rates will be larger. The errors of BLRs sizes don't effect our calculated inclinations too much compared to the influence of B magnitude.

	δi_1	δi_2	δi_3	$\delta \dot{M}_1$	$\delta \dot{M}_2$	$\delta \dot{M}_3$	δM_1	δM_2	δM_3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
upper limit	15.10 ± 1.98	13.78±1.72	3.17±0.46	0.73±0.26	0.49±0.09	0.67±0.02	1.10±0.03	0.95±0.02	0.63±0.007
lower limit	11.16±7.06	10.56±6.47	2.91±1.65	0.60±0.14	0.45±0.06	0.66±0.02	1.09±0.04	0.89±0.04	0.63± 0.007

Table 3. The mean and the error of uncertainties of our results for 15 Seyfert 1 galaxies (exclude IC4329A, NGC3227 for their unavailable lower limit of BLRs sizes). Column (1) to (3) are uncertainties of calculated inclinations, δi. Column (4) to (6) are uncertainties of calculated accretion rates, $\delta \dot{M}$. Column (7) to (9) are uncertainties of calculated BH masses, δM. Column (3), (6) and (9) is the values just considering the effect of uncertainty of Q. Column (2), (5) and (8) is the values considering the effect of uncertainties of Q and B magnitude. Column (1), (4) and (7) is the values considering the effect of uncertainties of Q, B magnitude and size of BLRs.

	δi_1	δi_2	δi_3	$\delta \dot{M}_1$	$\delta \dot{M}_2$	$\delta \dot{M}_3$	δM_1	δM_2	δM_3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
upper limit	4.72 ± 0.90	4.23±0.80	0.84±0.16	0.67±0.07	0.41±0.001	0.65±0.001	1.15±0.02	1.00±0.001	0.65±0.002
lower limit	2.58±0.49	2.47±0.47	0.73±0.14	0.56±0.02	0.41±0.002	0.65±0.001	1.26±0.07	1.00±0.002	0.65± 0.003

Table 4. The mean and the error of uncertainties of our results for 16 PG quasars (exclude PG1700 for unavailable lower limit of BLRs sizes). Column (1) to (3) are uncertainties of calculated inclinations, δi. Column (4) to (6) are uncertainties of calculated accretion rates, $\delta \dot{M}$. Column (7) to (9) are uncertainties of calculated BH masses, δM. Column (3), (6) and (9) is the values just considering the effect of uncertainty of Q. Column (2), (5) and (8) is the values considering the effect of uncertainties of Q and B magnitude. Column (1), (4) and (7) is the values considering the effect of uncertainties of Q, B magnitude and size of BLRs.

α	1	0.1	0.01
Seyfert 1	0.33±0.15	0.99±0.18	1.72±0.19
PG quasar	1.83±0.20	2.58±0.20	3.34±0.20

Table 2. The mean and the error of ΔM in logarithm for Seyfert 1 galaxies and PG quasars considering $\alpha = 1, 0.1, 0.01$ and $Q = 1$.

4. Discussions and Conclusions

4.1. The large accretion rates for Seyfert 1 galaxies.

In Fig.7 and Fig.8, though the accretion rates in units of the Eddington accretion rates for PG quasars are consistent with the results of Laor (1990), we can see that accretion rates in units of the Eddington accretion rates of the most of Seyfert 1 galaxies is larger than one. We confirmed the results of Collin & Hure (2001). They also find it radiates at super-Eddington rates if a standard accretion disc accounts for the observed optical luminosity. They can't account for the effect of the inclination. In this paper we consider the effect of the inclinations and uncertainties of accretion rates from Q, BLRs sizes and B absolute magnitude. Although we find there also exists high accretion rates for Seyfert 1 galaxies, we should notice the uncertainties about accretion rates (Fig. 8). The large accretion rates are maybe due to the uncertainty of dynamics of BLRs, median absolute B magnitudes. More knowledge of BLRs dynamics, accretion disks and optical luminosity are needed to improve the determinations of accretion rates in AGNs.

4.2. The disk inclination to the line of sight

With our calculation, there is apparent difference in inclinations between Seyfert 1 galaxies and PG quasars (Fig.3, Table 1) when we adopt $\alpha = 1$ for all objects. Inclinations for quasars are smaller than that for Seyfert galaxies. The mean and error of inclinations for 17 Seyfert 1 galaxies are 32.2±5.5 (deg) ($\alpha = 1$). The mean and error of inclinations for 17 PG quasars are 5.65 ± 1.08 (deg) ($\alpha = 1$). Only 4 quasars have inclinations larger than 10^o. The mean uncertainty of inclinations of quasars is large, about 4.7^o (Table 4). The mean value of inclinations for PG quasar can be about 10^o as upper limit considering the uncertainties of Q, BLR sizes and B magnitude. We noticed that the ratio between the black hole mass determined by reverberation mapping technique (M_{rm}) and our calculated black hole mass (M_{cal}) can be approximated by $3(sini)^2$ (Wu & Han, 2001). With the mean value of inclinations (32^o) derived by us, we obtained $M_{rm}/M_{cal} = 1.19$ for Seyfert 1 galaxies. It means that the black hole mass estimated by the standard method of reverberation mapping can still represent the "true" black hole mass well if the inclination of the Seyfert galaxy is not substantially different from 32^o. With the mean value of inclinations (5.65^o) derived by us, we obtained $M_{rm}/M_{cal} = 34$ for PG quasars. According to our model and when using $\alpha = 1$, it is necessary to consider the effect of inclinations to calculate the central black hole masses for quasars.

Based on AGNs unification schemes, AGNs with wide emission lines from BLRs are oriented at a preferred angle from which BLRs is visible. No edge-on disks would be seen (Urry & Padovani 1995). Our calculated inclinations, with a mean value of 32^o for 17 Seyfert 1 galaxies that agrees well with the result obtained by fitting the iron $K\alpha$

lines of Seyfert 1 galaxies observed with ASCA (Nandra et al. 1997) and the result obtained by Wu & Han (2001), provide further support for the orientation-dependent unification scheme of active galactic nuclei. Based on the unified model of AGNs, the wide variety of AGN phenomena we see is due to a combination of real differences in a small number of physical parameters (e.g. luminosity) coupled with apparent differences which are due to observer-dependent parameters (e.g. orientation). The unification scheme does not explain the difference between Seyfert 1 galaxies and quasars in an inclination effect (as they both should have the same inclinations of close to face on) but explain it as a luminosity difference. We here find that inclinations of PG quasars are smaller than that of Seyfert 1 galaxies if we adopt the same value of α for all objects (Fig.3, Table 1) . Do luminous quasars prefer to face on ? We adopt different values of parameter α and try to bring quasars inclinations to the inclination levels of Seyfert 1 galaxies. We use larger α to recalculated inclinations for PG quasars. The mean and error of inclinations for 17 PG quasars is $13.4^{+10.4}_{-5.8}$ (deg) ($\alpha = 10$) and $29.7^{+15.0}_{-12.0}$ (deg) ($\alpha = 100$), which are in the inclination levels of Seyfert 1 galaxies. The errors of Q, absolute B band magnitude, BLRs sizes are considered to calculate the uncertainties of inclinations. It is possible that the difference between PG quasars and Seyfert 1 galaxies is maybe due to the difference of the value of α. From above all we may find calculated inclinations of PG quasars are smaller than that of Seyfert 1 galaxies unless we adopt larger value of α for PG quasars to calculate in our model. However we often assume that the value of α of disc in AGNs is often between 0 and 1 (Shakura & Sunyaev 1973) . The need of higher value of α (larger than one) for PG quasars maybe shows that our model is not suitable for PG quasars if we think inclinations of PG quasars are in the inclination levels of Seyfert 1 galaxies.

In Fig.3 we can find the NLS1s (here we simply define the NLS1s with FWHM of Hβ is less than 2000 kms^{-1}) have the smaller inclinations except for NGC4051. We should notice the larger scatter about the value of inclination for NGC4051 (Table 1). Collin & Hure (2001) suggested the sizes of the BLRs will increase with the accretion rates expressed in Eddington units and decrease with the black hole masses. The larger size of BLRs led to the smaller widths of Hβ in NLS1s. They omitted the effect of the inclinations. The virial BH mass is given by $M = \frac{V^2_{FWHM}}{4(sini^2+A^2)}RG^{-1}$. Because the difference for the sizes of BLRs is not big, NLS1s with small values of V_{HWHM} will have smaller BH masses when we don't consider the effect of inclinations. The effect of inclinations in NLS1s should be considered when we study the physics of NLS1s. In Fig.6 we show the velocity of BLRs and we find the intrinsic widths of Hβ for NLS1s are not smaller than that of broad line AGNs, which is different from the results of Wu & Han (2001), which is from 11 Seyfert 1 galaxies.

4.3. The size of BLRs

There is a natural idea that BLRs are made of the atmosphere or winds of giant stars (Edwards 1980). Another idea is that BLRs are from the accretion disk or the wind released at the top of the disk (Murray & Chiang 1997). With the reasonable values of M_{cal} and inclinations, we show that the gravitational instability can indeed explain the size of BLRs. Assuming the gravitational instability of standard thin accretion disk leads to the Broad Line Regions(BLRs), the B band luminosity comes from standard thin disk and the motion of BLRs is virial, we can obtain $R_{BLR} \propto L_B^{0.5}\dot{M}^{-37/45}$ from Eq. 1 and Eq. 2. If $L_{5100} \propto L_B$, there is a correlation $R_{BLR} \propto L_{5100}^{0.5}\dot{M}^{-37/45}$. The size of BLRs relates not only to the luminosity, but also to the accretion rates. Nicastro (2000) proposed that the BLRs are released by the accretion disk in the region where a vertically outflowing corona exists and he found the sizes of BLRs would relate to $\dot{M}$. Collin & Hure (2001) showed the size of BLRs mainly related to M, not $\dot{M}$. Based on the formulae $R_{BLR} \propto L_{5100}^{0.5}\dot{M}^{-37/45}$, the difference of the accretion rate for the Seyfert 1 galaxies is not much and there is a relation as $R_{BLR} \propto L_{5100}^{0.5}$, the power index is almost 0.5, which can explain the correlation between the size of BLRs(R_{BLR}) and the monochromatic luminosity at 5100Å(L_{5100}), $R_{BLR} \propto L_{5100}^{0.5}$ (Wandel et al. 1999). The $\dot{M}$ is different for Seyfert 1 galaxies and quasars. The $\dot{M}$ of luminous quasars are small (see Fig.7, Fig.8). The index will be higher for the sample of Kaspi et al. (2000) which includes 17 Seyfert 1 galaxies and 17 PG quasars. It is necessary to check this with a larger sample.

4.4. Conclusion

With the formulae of the standard thin disk and the assumption of gravitational instability leading to BLRs, we calculate the central black hole masses, accretion rates and inclinations for 34 AGNs. The main conclusions can be summarized as follows:

- The gravitational instability can indeed explain the size of BLRs. The size of BLRs relates not only to the luminosity, but also to the accretion rates.
- Our results are sensitive to α parameter of the standard α disk. α is 1 in all the calculations. The mean value of inclinations for 17 Seyfert 1 galaxies is 32^o , which is favoring the orientation-dependent unification scheme of AGNs. Inclinations of 17 Seyfert 1 galaxies are about 6 times larger than that of 17 PG quasars unless the value of α of PG quasars is larger than Seyfert 1 galaxies. The need of higher value of α for PG quasars maybe shows that our model is not suitable for PG quasars if we think inclinations of PG quasars are in the inclination levels of Seyfert 1 galaxies. There is a correlation between inclinations and the FWHMs of Hβ. Though the observed FWHMs of Hβ for NLS1s is smaller than that for broad line AGNs, the intrinsic of FWHMs of Hβ for NLS1s are not smaller than that of

broad line AGNs. Small inclinations lead to the small FWHMs of Hβ for NLS1s.
- The uncertainty of absolute B band magnitude (here we adopt 1 magnitude) from variability or the hosts contribution leads to larger scatter of our results than error of size of BLRs. More knowledge of BLRs dynamics, accretion disks and optical luminosity are needed to improve the determinations of black hole masses, accretion rates and inclinations in AGNs.

Acknowledgements. We thank Keliang Huang for useful discussions, and the anonymous referee for the valuable comments.

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